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On the Development of Controllable Sources of Single-Photon States with an Orbital Angular Momentum on the Basis of Spontaneous Parametric Down-Conversion of Light

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Abstract—Methods for beam shaping with nonzero orbital angular momentum are studied using diffraction optical elements with the purpose of developing a source of single-photon states based on spontaneous parametric down-conversion of light in the $LiNbO_3$ crystal in the cavity resonator. The probability of the coincidence of the number of photocounts in detecting signal and idle fields under pumping by a beam with the orbital angular momentum is simulated.

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Introduction. Quantum optical communication provides absolute security of transmitted data coded in quantum states [1, 2]. The single-photon states in which information is coded are chosen from the degrees of freedom of the electromagnetic field, such as the polarization, frequency, and others. One of such degrees of freedom is the orbital angular momentum (OAM) [3]. The use of photons with nonzero OAM allows an increase in the information capacity of the communication channel and data transmission distance limited by losses in optical fiber and open space.

Currently, optical communication lines are mostly organized using attenuated laser pulses. However, since the Poisson statistics of laser radiation admits the presence of several photons per pulse, even significant attenuation of laser pulses does not provide absolute security. Therefore, the development of sources of single-photon states with nonzero OAM is an urgent problem.

To generate single-photon states at the wavelength of 800 nm corresponding to one of atmospheric transmission windows, it is convenient to use spontaneous parametric down-conversion (SPDC) of light. Spectral properties of photons produced in such a way are well studied [4]. In this paper, we present the results of preliminary studies on the development of a system for generating single-photon states with nonzero OAM during SPDC of light beams with OAM, formed using diffraction optical elements (DOEs).

Methods for producing light beams. Currently, several methods for generating optical beams with OAM are known (see, e.g., reviews and references in [5]). Experimental studies show [6] that the highest energy efficiency is inherent to methods for generating such beams with radially symmetric intensity distributions (optical vortices) using DOEs containing phase distributions of a vortex lens and a vortex axicon [7],

$$\Phi_L(r,\varphi) = -\frac{\pi r^2}{\lambda f} + m\varphi, \tag{1}$$

$$\Phi_{ax}(r,\varphi) = -\frac{\pi r^2}{\lambda f} + \frac{\pi r_0 r}{\lambda f} + m\varphi, \tag{2}$$